Termites as an Urban Problem in South America

by

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ABSTRACT

New data on the distribution and infestation patterns of termites pests in South American urban areas are presented. This includes wood-feeding, arboreal, subterranean and soil-dwelling termites. The evolution of the infestation of the introduced subterranean termite, *Coptotermes havilandi*, is studied in the city of São Paulo and four historic phases are recognized. Changes in the control concepts in each phase are described. The complex interaction of urban areas, biology of the pest species, and control operations are discussed and they are considered decisive in the dynamism of the urban infestation by termites. The modifications of the original environment by the urban development, in association with the extinction of the native fauna, seems to influence strongly the success of pest termites in tropical environments.

INTRODUCTION

This paper is not a literature review of termite infestations in South American urban areas. The first three sections present infestation data for drywood, subterranean and arboreal termites, with case-studies and literature and original information. The fourth section is a discussion on the concepts of urban infestation by termites and control. The concepts discussed are not theoretical, but have arisen from, and are currently being applied to the authors' routine field work on termite infestation in Brazil.

The history of studies on termites in urban areas is rather recent in South America. Before the last 20 years, only scattered reports of infestation, control procedures and occurrences of termites are found. But the increased infestation of the early introduced subterranean termite, *Coptotermes havilandi*, in the Brazilian southeast region, and the more recent introduction, and increase in the infestation, of two species of *Reticulitermes* into the south region of the continent, have been starting points in urban termite studies. These took the form of four meetings and two books, that appeared previously to the XXI ICE.

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The **First Meeting of Termitologists of the Countries of the Mercosul** was held December 10 and 11, 1992, in Montevideo, Uruguay. Its purpose was to discuss the problems caused by *Reticulitermes lucifugus*, which is well established in Montevideo and inflicts severe damages to buildings and wooden structures. The next 2 meetings were held in the State of São Paulo, Brazil. The **Second Meeting of Researchers on Termites of the State of São Paulo, Brazil** was held in November 26, 1993, in Rio Claro. Its subject was “Termites as pest in urban and rural environments in the State of São Paulo”. Despite its regional approach, it included people coming from distant places in Brazil. Many pest control operators coming mainly from the large city of São Paulo attended the meeting and brought to light interesting questions concerning the control of subterranean termites in urban areas and their needs for a scientific knowledge on that subject. This meeting can be considered a historic moment in the relationship of pest control operators working on urban termite infestations and members of the scientific community, which, in the near future, will publish works on some urban issues. The **Third Seminar on Termites / Third Meeting of Researchers on Termites of the State of São Paulo, Brazil** were held February 1 to 3, 1995, in Piracicaba. The Annals of the event incorporated some papers presented in previous seminars and all papers presented at the Uruguayan meeting. They appeared as the first book on termites published in Brazil (Berti-Filho & Fontes, 1995), with chapters of termites as pest in rural and urban areas and on termite biology and taxonomy. The **Second Symposium of Termitology of the Countries of the Mercosul** was held July 1 to 3, 1996, in Piracicaba. The papers presented, with the addition of new texts prepared by other authors, resulted in the second and largest Brazilian book on termites (Fontes & Berti-Filho, 1998), with chapters on applied termitology, biology, taxonomy and phylogeny, fossils, archaeology, folklore and a section about the pioneering termitologists, that was discussed at the meeting.

The events mentioned above have been strongly directed to the pest control operators (PCOs), in addition to members of the scientific community. They have positively contributed to the development of studies on termite infestations in urban and rural areas, and condensed much information and many concepts. As an example of the latter, it is worth mentioning the concept of esthetic pest, introduced by Fernandes *et al.* (1998) in the second Brazilian book on termites. Because mound building termites have always been considered pests of pastures, without scientific confirmation of their pest status, control has always been indicated by tradition. The concept of esthetic pest thus expresses

the authors' affliction of the psychological inconvenience caused to farmers and common people, by the simple presence of the mounds in the pasture landscape. It contrasts with the traditional concept of economic pest. Indeed, farmers are frightened at the simple thought of termites, and they do not know that the underground harbors a much larger numbers of termites than the surface mounds, which are responsible for maintaining the balance of the soil structure.

The major difficulties for an adequate knowledge of the problems caused by termites and their control in South America seem to involve the scarcity of published information on these subjects, the small number of termitologists (most of them are concentrated in some parts of Brazil and Argentina), the proliferation of false concepts about termites among common people, and some older academic and reference books, that include wrong identification of pest termites, or assign as pests of certain crops a number of inoffensive termites. Another major issue, that will be considered ahead in the discussion, is the still incipient participation of PCOs in the investigation of termites in urban areas.

Unless otherwise stated, data presented in the following sections are original studies of the authors. The geographic coordinates of the cities mentioned are listed after the bibliography.

DRYWOOD TERMITES

The economically most important drywood termites in South American urban areas are three introduced species of *Cryptotermes*. Few damages are attributed to the native species of Kalotermitidae. Indeed, very little has been recorded on the South American urban drywood termites.

The most important species is *Cryptotermes brevis* (Walker), originally described for Jamaica. It is presumed native to the West Indies and north region of South America. The termite has a large-scale history of introductions, is now tropicopolitan in distribution, and has extended its range into subtropical regions too (Edwards & Mill, 1986, Fig. 7; Bacchus, 1987: 2-5). The distribution map of *C. brevis* in South America (Fig. 1) includes previous data obtained from the literature (Araujo, 1970: 539-540; 1977: 12; Araujo & Fontes: 1979: 34; Bacchus, 1987: 42; Bandeira *et al.*, 1998: 78; Fontes, 1998c: 322), except for the Brazilian Amazon region, for which Mill (1991: 343) quoted no localities, although he mentioned that the species is one of the commonest structural pests in domestic buildings. New localities in Brazil are Porto Alegre and Caxias do Sul, in the State of Rio Grande do Sul, Castro, in the State of Paraná, Florianópolis, in the State of Santa Catarina,

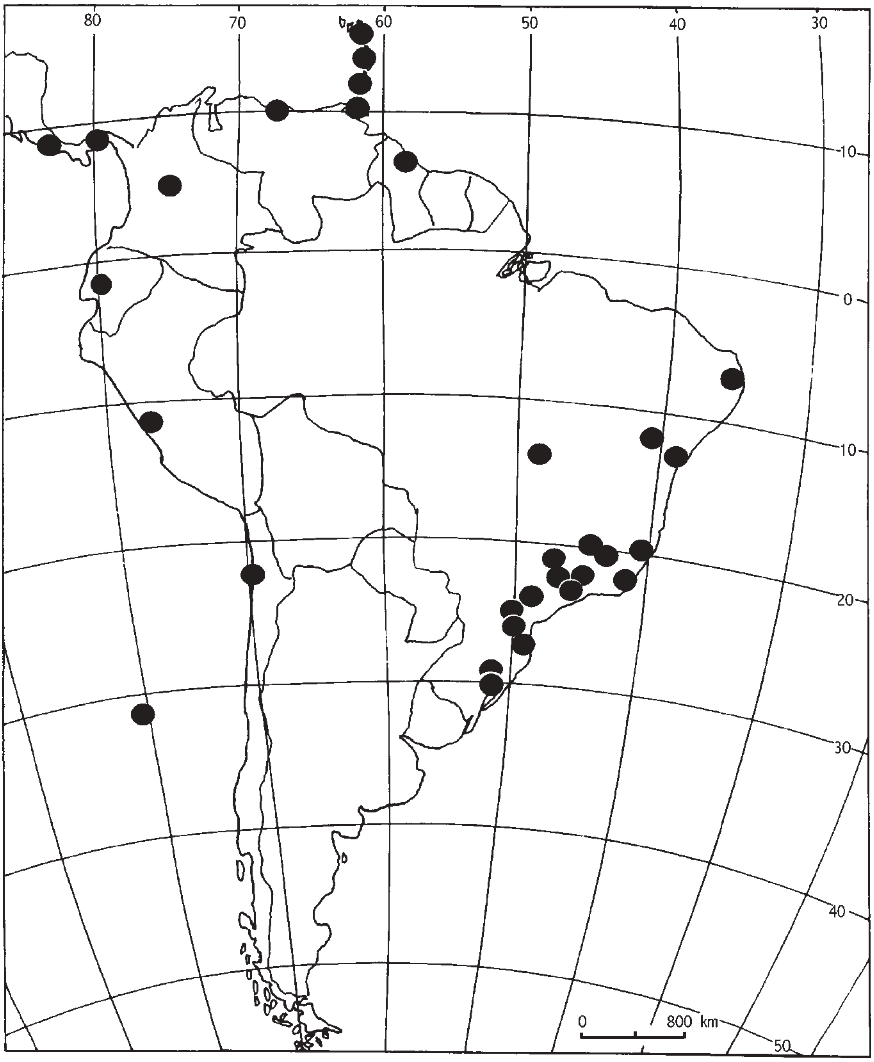

Fig. 1. Distribution of *Cryptotermes brevis* in South America.

Bananal, Pindamonhangaba, Ribeirão Preto and Santana do Parnaíba, in the State of São Paulo, and Ouro Preto and Congonhas, in the State of Minas Gerais. *C. brevis* is clearly well distributed in the periphery of the continent and is present in central Brazil. New collections will certainly enlarge its geographical distribution, but the species seems to be absent in some countries, such as Argentina (Torales *et al.*, 1997; Torales, 1998). In Uruguay, although the termite was listed by Bacchus

(*l.c.*; sample collected by F. Silvestri in 1920, probably in Montevideo), it is not mentioned by Aber (1995) and seems to be considered of minor importance. In Brazil, *C. brevis* is a serious pest of the structural wood of historic buildings, and of valuable historic goods in the cities reported for the States of Minas Gerais (several historic cities, like Ouro Preto, Mariana and Congonhas), São Paulo and Paraná.

Cryptotermes dudleyi (Banks), apparently of oriental origin, is assigned as a pest in Belém, State of Pará, and in the Brazilian Amazon region (Bandeira, 1998: 89). A species that is probably *C. dudleyi* is also pest in João Pessoa, State of Paraíba, in the northeast region of Brazil (Bandeira *et al.*: 78). The termite was collected in 1953 in Rio de Janeiro, in the southeast region of Brazil (Araujo, 1970: 540), but has not been found again in that city. *C. dudleyi* was reported from Colombia (Araujo, 1977: 14), although we were unable to find the exact locality. We have examined a sample of *C. dudleyi* from Johny Cay, San Andres Island (12°28'55"N, 81°40'49"W), Colombia, but this is in the Caribbean sea.

Cryptotermes havilandi (Sjoestedt) is an African species, now established in northern South America. It was reported from Guyana, Suriname and Brazil (see Araujo, in Mariconi *et al.* 1980: 107). The termite was collected in several regions of Brazil: Santos, State of São Paulo, and Rio de Janeiro, State of Rio de Janeiro, in the southeast region (*l.c.*); Fortaleza, State of Ceará, in the northeast region (Araujo & Fontes, 1999: 55); Belém and Icoaraci, State of Pará, in the Amazon region (Constantino & Cancello, 1992: 402). Mill (1991: 343) reported that *C. havilandi* is a common structural pest in domestic buildings in Brazilian Amazonia.

Other drywood termites were reported as pests of structural wood, fences and furniture, of the genera *Cryptotermes*, *Glyptotermes*, *Neotermes* and *Tauritermes* (Fontes & Araujo, 1979: 34; Mill, *l.c.*; Bandeira, 1998: 89), but their role in urban areas is unknown.

SUBTERRANEAN TERMITES

Subterranean termites are a serious problem in urban areas. They are commonly voracious and endogenous in the building structure and urban trees, showing little or no signs of their presence, except under severe infestations, when external tunnels are evident.

We recognize two groups of pest subterranean termites, according to their geographic origin. There are native pest species, of the genera *Heterotermes*, *Rhinotermes* and *Coptotermes*, for which knowledge is still incipient. It is difficult to assign their role as urban pests, but in most cases they seem to act as pests of minor importance or opportunists. A group of major importance is that of the introduced species, that

have arrived from other geographic regions of the world and are now expanding their range in South America. In this group we mention *Coptotermes havilandi,* introduced into the southeast region of Brazil in the beginning of the last century (or earlier), and two species of *Reticulitermes*, whose recent introductions (about the last three or four decades) in Uruguay and Chile constitute the most spectacular historic

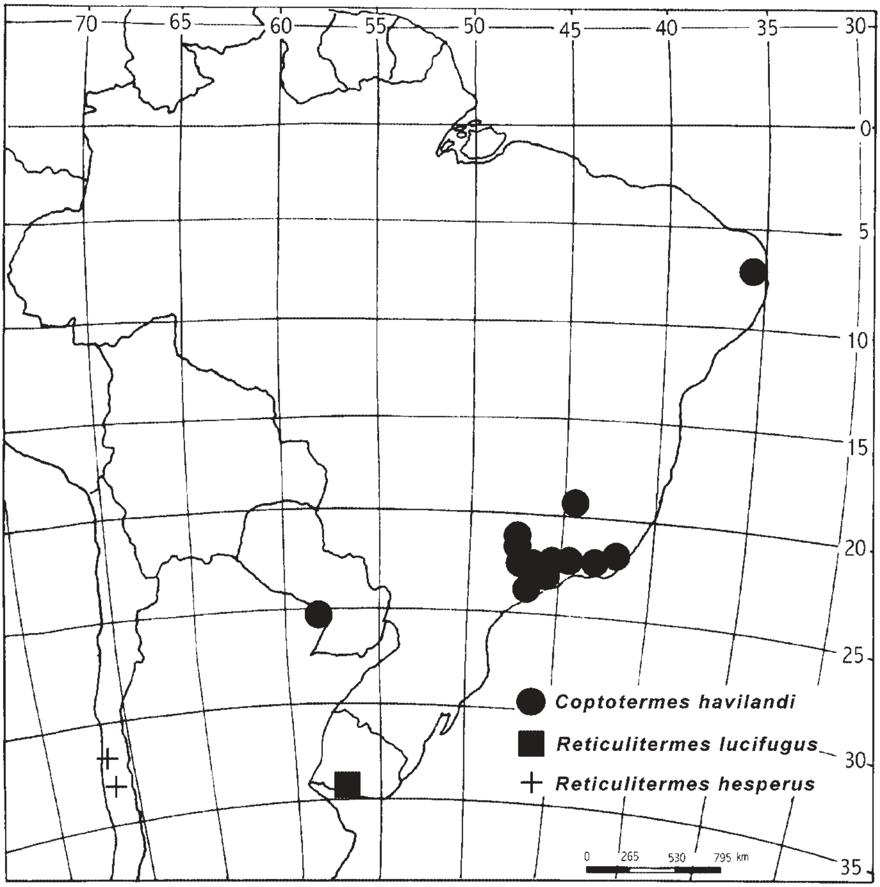

Fig. 2. Distribution of *Coptotermes havilandi*, *Reticulitermes lucifugus* and *R. hesperus* in South America.

event of the last half of the past century, on South American termites (Fig. 2).

The tunnels built by subterranean termites are commonly brown to light brown, with the inner surface lined with a brown to yellowish mosaic covering of fecal spots. The attacked surfaces commonly are also

partly or totally lined with a mosaic of light spots. These are good indicators of an attack by subterranean termites, contrasting with the

Fig. 3. Left: piece of wood attacked by *Coptotermes havilandi*. Note pale covering of fecal matter. Right: piece of wood attacked by *Nasutitermes corniger*. Note the dark covering of fecal matter.

dark tunnels and linings made by arboreal and soil-dwelling termites (Fig. 3).

COPTOTERMES

Two species of *Coptotermes* are economically important in Brazil. The native *C. testaceus* is mainly a pest of artificial forests, while an introduced species, *C. havilandi*, is a serious pest in urban regions. The latter is the urban most destructive subterranean termite (Fig. 4).

Mill (1991: 343) mentions *C. testaceus*, *C. havilandi* and *C. niger* among the commonest structural pests in domestic buildings in the Brazilian Amazonian region, and Bandeira *et al.* (1989: 12) and Bandeira (1998: 90-92) report *C. testaceus* as pest of buildings in

Fig. 4. Electrical box filled with carton mass of *Coptotermes havilandi* (right) and switch plate (left). Third floor of a building in São Paulo, State of São Paulo, Brazil.

Belém, Pará State and Manaus, Amazonas State.

C. havilandi (Holmgren) is the best studied subterranean termite (Lelis, 1995; Fontes, 1995, 1998a; Costa-Leonardo & Barsotti, 1998, 2001; Costa-Leonardo *et al.*, 1999; Fontes & Araujo, 1999). Reviews on the complexity of the problem caused by the termite in urban areas are presented in the papers of Fontes (*l.c.*) and Fontes & Araujo (*l.c.*) and some aspects of this interesting subject are discussed elsewhere. *C. havilandi* is clearly expanding its geographic range, from city to city. Such discontinuous, distant introductions are caused by human transportation, while within each city dispersal seems to occur mainly in a continuous way from the original introduction point (or points) through swarmings. Its introduction into new, previously non infested areas, brings to light a new dimension on the problem of street trees and building infestations, and on the complex operations required to control the termite. PCOs are requested to raise the issue of *C. havilandi* infestation and control, as one of the major challenging urban problem in Brazil.

C. havilandi is an Oriental termite, reported for the first time in the

Neotropical Region by Lima (1939: 278, as *C. vastator* Light), in Rio de Janeiro, Rio de Janeiro State, Brazil. Subsequently, Araujo (1958: 194; 1970: 542; in Mariconi *et al.*, 1980: 110) remarked that specimens of *C. havilandi* (identified by A. E. Emerson; see Araujo, 1958) were first collected in Rio de Janeiro, Rio de Janeiro State, in 1923, and in Santos, São Paulo State, in 1934. It was clearly introduced in earlier decades, since Araujo (in Mariconi *et al.*, *l.c.*) informed that "*... in Rio de Janeiro, in 1923, ... at the swarming season, the amount of alates in flight looks like large clouds along entire streets*".

The southeastern coastal cities of Rio de Janeiro and Santos, distant each other about 500 km, have economically very important harbors and are historic commercial routes to the inland country. The introduction of *C. havilandi* probably occurred in the second half of 19th century, from infested material unloaded off ships or from swarmings coming from infested ships (Fontes & Araujo, 1999: 67). Currently, although rare, ships can house infestations of *C. havilandi*, as seen in Rio de Janeiro (Sérgio C. Carvalho/Insetisan Ltd., personal information). No intermediate infestation has been ever detected in rural places and in areas of preserved natural vegetation (from open fields to forests) and it is fairly reasonable to state that the termite has been disseminating to other cities by human transportation. If the dispersal towards the west cities has occurred (and still occurs) by transport, it seems most probable that incipient colonies (from dealate couples to small young colonies recently established in suitable places, like living plants with soil, earth with vegetal debris, rubbish and waste material, cardboard boxes, large paper reels, and other items) are the best candidates to be dispatched and to establish new infestations into new cities. Such mechanisms would imply a rather slow emergence rate of new evidently infested cities, since new colonies grow slowly through several years, initial swarmings may be discrete and inconspicuous for the common people, as may also be the pioneering infestations, that can inconspicuously develop in trees, instead of buildings. In fact, the initial dispersal of the termite was quite slow. The great São Paulo city, only 70 km from Santos, showed large swarmings about 30 years later, in the ending 60´s or beginning 70´s (Araujo, in Mariconi *et al.*, *l.c.*: 111; personal communication of R. L. Araujo to the senior author in 1978). From the 80´s on, the termite has dispersed largely, either in the surroundings of the mentioned cities as towards the west cities of the country. In 1997, *C. havilandi* was found in Recife (Fontes & Veiga, 1998; Araujo & Fontes, 1999: 67), in the Brazilian northeast coast, 2300 km north of the original introduction cities.

Case 1. Recife, State of Pernambuco, Brazil. Infestations by *C.*

havilandi occur in some urban areas. In February 2001 we inspected some large hangars in the Jequiá District, where pallets with a variety of products were stored. The buildings were infested by *C. havilandi* and most severely by two species of *Nasutitermes* (the most common was *N. corniger*; see next item). The subterranean termite emerged from the floor joints, invaded the piles of double-decked pallets and consumed the deckboards and stringers. Tunnels reached about 2 m high in the piles and sometimes carton masses appeared in the pallet entries (Fig. 5). The floor joint vains were full of termite tunnels. The floor was elevated in many parts of the hangars and the termites were nesting in

Fig. 5. Piles of double-decked pallets with carton mass in a pallet entry. Note the pale covering of fecal matter. Recife, State of Pernambuco, Brazil.

the cavities below the floor.

Mr. Itiel Genes, an experienced pest control operator for more than 40 years in the city of Recife, informed us that urban infestations by *Coptotermes* occurred in the last 20 years and are gradually becoming more frequent. According to him, there are aerial infestations in large buildings, as described for the large cities of the Brazilian southeast region, although the problem is far less disseminated.

Case 2. Belo Horizonte, State of Minas Gerais, Brazil. The urban infestation by *C. havilandi* is restricted to some areas of the city, like Gutierrez and Savassi Districts. There are infestations in houses and

large buildings, either connected to the ground or purely aerial infestations, but these issues have not yet been investigated. Infestation of urban trees has not reached the severity known from cities with a more ancient infestation history, like São Paulo (Fontes, 1995; 1998a).

According to the biologist and PCO, Mr. Horácio C. Cunha, infestation by *Coptotermes* is quite recent in Belo Horizonte. He was first requested to control a *Coptotermes* infestation in 1996, in a house.

C. havilandi infests many cities in the southeast region of Brazil, such as the Rio de Janeiro great metropolitan area, Niterói, Cabo Frio and Seropédica, in the Rio de Janeiro State, Santos, São Vicente, Guarujá, São Paulo great metropolitan area, Campinas, Piracicaba, Rio Claro, Limeira, Porto Ferreira, Taubaté, Jacareí, in the São Paulo State, and Belo Horizonte, in the Minas Gerais State. In the northeast region, *C. havilandi* occurs in Recife, State of Pernambuco. Other locality reports from the literature should be verified, since the correct identification of *Coptotermes* species is not an easy task.

In the end of year 2000, we received from Dr. Enrique Laffont (University of Corrientes, Argentina) three termite samples from Asunción, Paraguay. They were collected by him November 22 and 23 in 1998, infesting two living ornamental trees (Flamboyant or *Delonix regia*, and *Peltophorum dubium*) and one dead tree in the University of Paraguay. The species was identified by L. R. Fontes as *Coptotermes havilandi*, and this is the first report of the species outside Brazil in the South American continental area.

RETICULITERMES

Reticulitermes occurs in the North Hemisphere, with several economically important species. The genus has 7 species in the American continent. Six species are native in the Nearctic region. One of them, *R. flavipes*, extends its geographic range as far south as Guatemala, in Central America, and *R. hesperus* was introduced in Chile. A seventh species, *R. lucifugus*, originated in the Mediterranean area and was introduced into Uruguay.

Reticulitermes lucifugus (Rossi) was introduced in the city of Montevideo, Uruguay, probably in the decade of 1960 (Aber & Fontes 1993). The termite is disseminating and extending its geographic range to the neighbor districts and infestations now occur also in the downtown area (Aber 1998).

The history of infestation by *R. lucifugus* in Montevideo is fairly recent (Aber & Fontes *l.c.*). Infestations were first noticed in 1968 and became a social problem in 1976, in the district of Carrasco Norte. This district, now mainly residential, also has several important national and

multinational manufacturers and factories and is in close vicinity to the international airport of Montevideo. Any of these could have been involved in an involuntary importation of the termite. Colonies of *R. lucifugus* are common in logs, standing dead trees in private and public gardens, especially eucalyptus artificial forests in the urban area, all representing permanent reservoirs of the termite and sources for the infestation of urban structures.

A voracious pest of structural wood as *R. lucifugus* was previously an unknown problem in that temperate country and it represents a real risk of introduction also into the important neighbor city of Buenos Aires, Argentina, and into the south region of Brazil, through the commercial routes to the Rio Grande do Sul State.

Reticulitermes hesperus Banks was reported from Chile in 1986 and is now an important pest of structural wood and urban trees in the cities of Santiago and Valparaiso (Cabrera & Camousseight, 1997, 1998). Its introduction probably occurred earlier than 1986, because in 1998 the termite was widespread in Santiago, with at least 80 infested areas occurring in 29 districts, including the downtown area. Cabrera (1997) attributed the dispersal of the termite inside the urban areas mainly to the human transportation of construction debris and rubble, plant debris, packaging, earth and living plants with clods, since it is certainly faster than by the naturally occurring swarmings. She also reported damages to plastics, asbestos, aluminum, plaster, polystyrene, cardboard, paper and flax, and attacks to the dead parts of plants in gardens.

HETEROTERMES

Species of *Heterotermes* are important pests of eucalyptus forests and the sugar cane culture, in some regions of Brazil. They seem to be casual pests of rural constructions, poles and fences. Some species cause urban infestations (Fig. 6), but the damage they inflict to wood structures is much less important, when compared to that caused by species of *Coptotermes* and *Reticulitermes*.

In some regions, species of *Heterotermes* are regarded as important urban pests, as in João Pessoa, State of Paraíba (Bandeira *et al.* 1998: 79). In Uberlândia, State of Minas Gerais, the agronomist and PCO, Mr. Telmo Vinicius (personal communication) reports that infestations of houses and factories are common in the urban and suburban areas. He also informs that infestations occur in the upper floors of high buildings in Uberlândia.

The importance of *Heterotermes* infestation is clearly underestimated and deserves the attention of collectors.

Case 3. Brasília, capital of Brazil. The Catetinho Museum, mark of

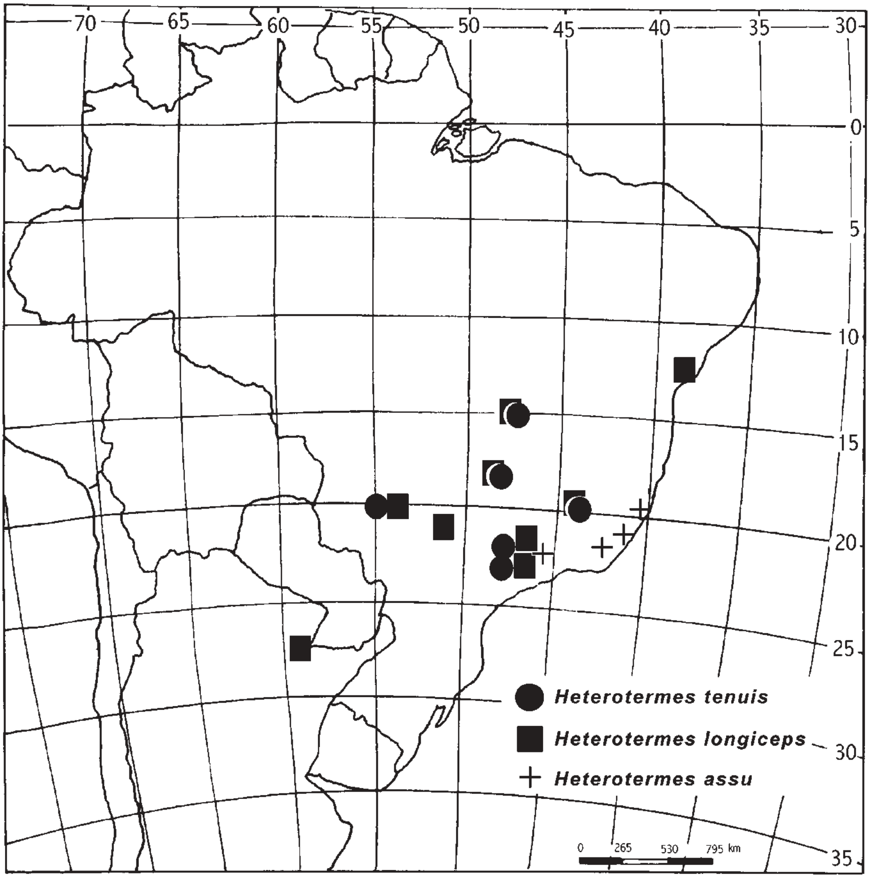

Fig. 6. Distribution of *Heterotermes tenuis*, *H. longiceps* and *H. assu* in South American urban areas.

the foundation of the city, is a two-stories high building made of wood, in a suburban park. In 1995, it was severely infested by the common drywood termite, *Cryptotermes brevis*. However, the base of the wood studs and some boards of the walls, at the first floor, were infested by *Heterotermes tenuis* and also by *H. longiceps*. They inflicted severe damage, restricted to the woods in close proximity to the ground. The boards attacked also showed damage made by fungi, and the base of the studs was rotten due to the high degree of humidity under the floor (the floor was made of a concrete layer, enclosing the base of the studs). The infestation by *Heterotermes* seemed opportunist, favored by the excessive humidity under the floor.

Case 4. Porto Feliz, State of São Paulo, Brazil. An old one-story farm

house, with brick walls that were cemented with a clay mixture, was severely infested by *H. tenuis*. Pieces of the plaster that covered the outer walls were removed on 4 December, and many alates were collected from the cavities below the plaster. On 17 December 2000, the plaster was totally removed and this enabled a careful investigation of the termite invasion. Chambers and tunnels were excavated in the clayey wall cement and the termite reached the woods of the roof, about 3.5 m above ground. Some bricks in the walls and some furniture were also damaged. The infestation was favored by the high humidity degree in the soil, below the house.

Case 5. Belo Horizonte, State of Minas Gerais, Brazil. Infestations by *H. longiceps* and *H. tenuis* occur scattered on the urban region. Attacks to fences seem to be common. Infestations of houses appear to be casual and commonly of minor importance. One case, however, investigated by the senior author and the biologist and local PCO, Mr. Horácio C. Cunha, was remarkable due to the severity of the damages. In the rooms adjacent to the terrain slope, there was a severe infestation and destruction of door jambs, thresholds and headers, and of some kitchen cabinets.

H. longiceps (Snyder) was reported as an important pest of historic and cultural buildings, their furniture, workmanship, works of art and books, in the city of Corrientes, Argentina (Torales, 1998: 416). Attacks are scattered in the city and include also houses. In Brazil, we report infestations by *H. longiceps* to the wood structure and furniture of houses and factories in Belo Horizonte and Uberlândia, Minas Gerais State, Campo Grande, Mato Grosso do Sul State, Brasília, the capital of Brazil, Presidente Prudente, Campinas and Itapira, São Paulo State, and Salvador, Bahia State.

H. tenuis (Hagen) is widely distributed in South America. It was considered an important pest of structural wood in domestic buildings in the Brazilian Amazônia (Mill, 1991: 343), but a minor pest in Belém, Pará State (Bandeira *et al.*, 1989; Bandeira, 1998: 91). We report infestations in some Brazilian cities, as Aquidauana, Mato Grosso do Sul State, Brasília, the capital of Brazil, and Uberlândia and Belo Horizonte, Minas Gerais State. *H. tenuis* infestations seem to be common in the rural area of Uberlândia, Minas Gerais State (T. Vinicius, personal communication) and of Piracicaba, São Paulo State (personal observations of L. R. Fontes).

Another species of *Heterotermes* was reported from the large city of São Paulo (Fontes & Araujo, 1999: 75), the economic heart of Brazil. The termite fauna of São Paulo and surrounding region has been extensively collected by Araujo, throughout his profitable scientific life, was also

visited and explored in 1937 by the Italian termitologist, Filippo Silvestri, and after 1977 has been investigated by the senior author. It is a reliable statement that the pest species has been introduced recently into the urban area of São Paulo (it was first collected in 1995, according to our records) and is gradually spreading and becoming more important as a pest of buildings (despite the fact that it is far less voracious than *Coptotermes havilandi* and much easier to exterminate). Fontes (in Fontes & Araujo, *l.c.*) proposed that it could have been imported from other regions of the world. That means that a long-term taxonomic study would be desirable, in order to define its species status, as is appropriate for any important pest species. The species was described as *H. assu* by Constantino (2000), who considered that it is native from the Brazilian Atlantic forest. Although this issue is not clear, his opinion is accepted in this paper.

We received a sample of *H. assu* from Petrópolis, State of Rio de Janeiro, Brazil. It was collected in 1987 and, according to the collector, the termite has severely damaged three houses at the city outskirts. Another sample from the same State came from Cabo Frio, collected on 2001 by Dr. André L. Barbosa, who informed us that it was collected under the bark of a tree. A sample was collected in São Paulo, São Judas District, in the beginnings of 2001, in the 18^{th} floor (top floor) of a residential building. According to biologist Beatriz Gromick, the termite was installed in structural voids (probably in the floor) and was attacking cardboard boxes.

RHINOTERMES

Rhinotermes marginalis (L.) was described for Suriname and occurs in the north of South America, mainly in the Amazon Region. The species was reported as a minor pest of structural wood in the Amazonas and Roraima States (Mill, 1991: 343) and in the city of Belém (Bandeira, 1998: 91), Pará State, Brazil. It was recently reported from the urban area of the city of Rio de Janeiro (Menezes *et al.*, 2000), State of Rio de Janeiro, in the southeast Brazilian coast, where specimens damaged skirtingboards in a mansion highly infested by *Coptotermes havilandi*. The mansion received chemical treatment and was monitored with pine stakes in the soil of the surrounding garden. *R. marginalis* was not collected again, within the next 6 months. This seems to be a case of species introduction, but the origin of the termite is unknown.

We recently received a sample of *Rhinotermes marginalis* from Vitória, State of Espírito Santo, Brazil. According to the information of Mr. Edson D. Rocha, an agronomist and experienced local PCO, the

termite is a pest of buildings in that city.

ARBOREAL NESTING TERMITES

Damages to all kinds of human properties and goods appeared early in the Brazilian literature, in texts dated from the discovery of the land in the 16th century (Cunha, 1989). The responsible for such attacks are species of the native fauna. Probably most were caused by species of *Nasutitermes*, common in the country and currently urban pests in several urban regions.

Despite our termite problems that are connected with the distant past, it is curious that previous to the rather recent introduction and increase of *Coptotermes havilandi* in urban infestation, which have come from other geographic regions of the world and become a problem in the last 40 years in the SE region of Brazil, no previous scientific reports were produced on the native fauna. Thus, there is a gap between the knowledge of our historically damaging original termites, and the more studied introduced termites.

NASUTITERMES

Infestations caused by species of *Nasutitermes* are common throughout South American urban areas (Fig. 7) but scarcely documented. Several species are involved, according to the geographic region (Bandeira *et al.*, 1989, 1998; Mill, 1991; Bandeira, 1998; Torales, 1998; Menezes *et al.*, 2000). Although some species are clearly opportunistic and infest badly preserved buildings or man-made structures, a small number are true pest species and may cause important economic losses and social disturb.

A noteworthy exception are the studies published by Torales and her collaborators (revised in Torales, 1998), about the infestation caused by *N. corniger* in the city of Corrientes, northeastern Argentina. Their studies provided a clear account of the damages caused by the termite in the urban part of Corrientes and revealed a case of introduction, whose expansion is being monitored by the researchers.

The taxonomy of the Neotropical species of *Nasutitermes* needs revision. There are about 70 valid names, some of which may prove to be synonymous, and several undescribed new species. Description of the alate caste is not available for many species and could provide a number of good distinctive characters. Information on nesting site and nest structure help much in the identification work, but they also lack for many species. When one compares samples from several colonies and localities, minor morphological variation (sometimes restricted to the alate caste) suggest that in some cases cryptic species may be

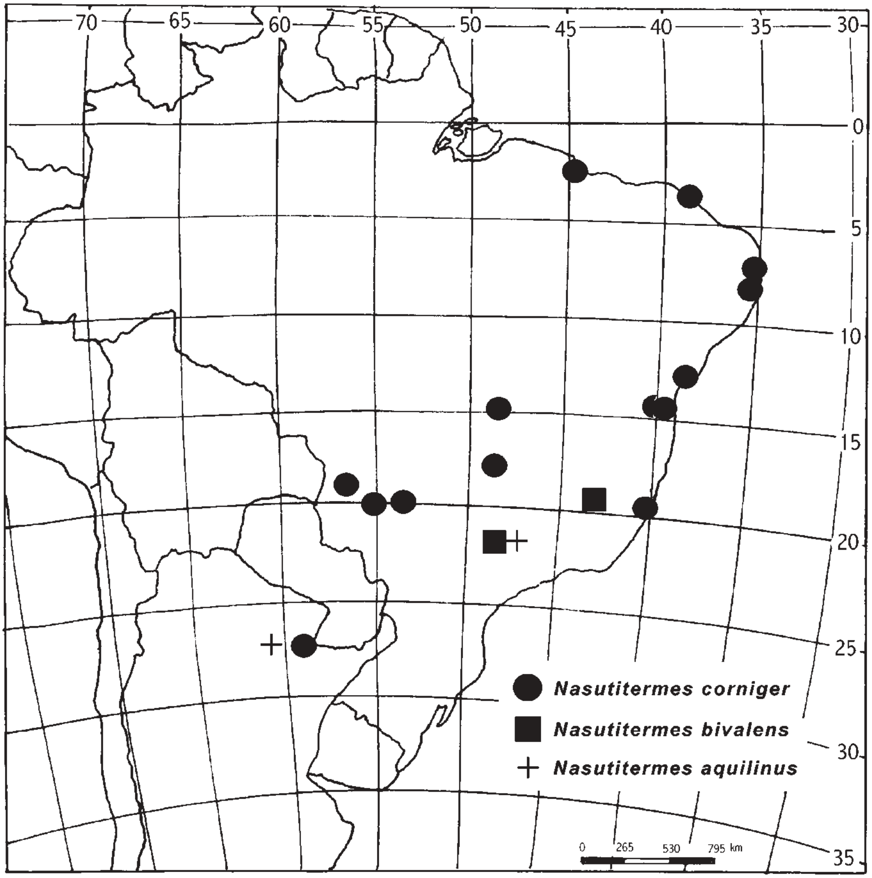

Fig. 7. Distribution of *Nasutitermes corniger*, *N. bivalens* and *N. aquilinus* in South American urban areas.

involved, and complementary morphological studies (including gut details) are needed to define their species status. Some identifications of pest species can change in the course of future taxonomic studies. Comments on the specific identification of some pest termites are presented in the following item.

PCOs can contribute greatly to the understanding of the taxonomy of *Nasutitermes* and other termites, as they have access to a very wide range of biological manifestations of the pest species (like nests, tunnels, damages, habits and particular behaviors) and can thus add much information to the specimens they collect.

Infestation patterns

Contrarily to the infestations caused by subterranean termites, infestations of *Nasutitermes* are apparent, because the tunnels are commonly built with dark carton and are easily visible on the exposed surface of walls, roofs and floors (Fig. 11). This can motivate great alarm among building proprietors and result in a false diagnosis of severe infestation by less experienced pest control operators.

The presence of dark tunnels are commonly good indicators of the infestation by *Nasutitermes*. The fecal markings of termite trails (Fig. 3),

Fig. 8. Roof beams attacked by *Nasutitermes corniger*. Note tunnel at a roof tile and a mass of dark carton covering inner face of a beam. Recife, State of Pernambuco, Brazil.

as the remains of the tunnels removed from walls, are also typically dark colored. In cases of hardly infested constructions, masses of dark carton frequently cover the exposed surface of pieces of wood (Fig. 8).

Like the subterranean termites, infestation caused by *Nasutitermes* can disperse in buildings through the soil below the ground floor and surrounding the walls, inside and outside electric and telephone conduits, following the passages of water and gas pipes, and through all kind of small spaces inside the walls and floors. Nests can be built inside structural voids (Fig. 12), sometimes in the upper floors of high buildings. It seems that pure aerial infestations also occur (see below).

The *Nasutitermes* that infest urban areas are commonly native species, but there are cases of introduction of species into urban areas where they were previously absent.

Two patterns of infestation can be recognized, according to the nesting habit. These patterns were defined in the course of an extensive study conducted by the senior author in several regions of Brazil, and also from the interpretation of PCO's information.

Exogenous (or arboreal) pattern

This is the common pattern of infestation, characteristic by the presence of conspicuous nests in posts, fences, walls, roof beams, trees and other supports made of wood or of brick and concrete. In buildings, nests are commonly found in the roofs and parametrical walls. The nests can also be constructed under floors and inside other hidden structural voids, although this seems to occur mainly under severe infestation.

The exogenous or arboreal pattern is associated to the infestation of urban trees, with typical arboreal nests of *Nasutitermes* seen in trunks and branches. Although it is not a rule, the urban trees can constitute an important reservoir of the termite.

This infestation pattern is common in South American urban areas. The main species involved seems to be *N. corniger* (Motschulsky). It is worth remembering that the first identification of *N. corniger*, from the city of Corrientes, by the senior author in 1983 (Torales & Armúa, 1985-86) may change in a future taxonomic study. The same (or a very close) species was recognized in samples from other cities, in several regions of Brazil. Thus, the previous accepted identification is convenient and must be retained until the taxonomic status of the pest species is clarified.

Case 6. Corrientes, Province of Corrientes, Argentina. The urban infestation caused by *N. corniger* is being currently investigated by G. J. Torales and her collaborators. This is an example of pest introduction, that probably occurred in the decade of 1950 (Torales, 1998: 417-419). Corrientes is a plain city in the margin of Paraná river, with few high buildings in the downtown area. Termite attacks are restricted to residential areas surrounding the presumable introduction site, but the distribution is enlarging. Nests are common in trees and roofs. Attacks are severe and can affect as much as 68.75% of the houses (Torales, *l.c.*).

Case 7. Corumbá, State of Mato Grosso do Sul, Brazil. Infestations caused by *N. corniger* are common in all urban areas and affect seriously the historic buildings of that previously important harbor city in the margin of Paraguay river. Trees are the main urban reservoir of the termite (Fig. 9). They are severely attacked and arboreal nests reaching as much as 70-100 cm in height are common in the main branch of the

Fig. 9. Living urban tree hollowed out by *Nasutitermes corniger*. Corumbá, State of Mato Grosso do Sul, Brazil.

trunk. Mainly the trunk of the Flamboyant tree (*Delonix regia*) can be hollowed and hide large infestation inside. Architect Cristiane C. F. Lopes, from the administration staff of the county, has stated that a popular saying in Corumbá urban area is "*the one with a Flamboyant tree in front of his house has termites inside the house*".

The same termites infest also the cities of Aquidauana and Campo Grande, State of Mato Grosso do Sul. Damages to rural buildings and trees are reported from Uberlândia and Brasilândia de Minas, in the State of Minas Gerais.

Case 8. Ilhéus, Itabuna and Salvador, State of Bahia; Recife, State of Pernambuco; João Pessoa, State of Paraíba; Fortaleza, State of Ceará; Alcântara, State of Maranhão; Brazil. *N. corniger* is the main pest termite in most coastal cities in the Brazilian northeast region. It is a permanent risk for the historic buildings and their collections of valuable old objects and documents. Nests are common in trees and can attain large size.

Bandeira *et al.* (1998) report that five species of *Nasutitermes* are pests in João Pessoa. All of them build nest on trees and occur in urban parks as in natural vegetation preserved areas.

Mr. Itiel Genes has given an interesting account about the evolution of the *Nasutitermes* infestation in the urban area. According to him, about 40 years ago, when he started working on control, the termite was considered a pest, but of minor importance in the more urbanized areas of the city. Damages to the wood frames of doors and windows, and to floors and roofs always demanded control in houses and small buildings, and arboreal nests were frequent in trees. The situation remained unchanged until the beginning of the 90's, when the problem started growing and now the termite problem is remarkable in some areas of the city. He reported that the increase in infestation has followed the historic changes in the urban soil occupation. Recife is a tourist city and, in the last 10-15 years, the lands bordering the seashore previously occupied by mangroves were heavily urbanized and are now occupied by large buildings. The original vegetation was destroyed and now the urban vegetation is different. Termite infestation seems to have grown in association with the changes in the urban profile, and the large buildings, full of structural voids, narrow fissures and wood, are very convenient for the termite exploration and nesting.

Mr. Itiel Genes also informed us that pure aerial infestations (this is,

Fig. 10. Polycalic nest of *Nasutitermes corniger* on a living tree. Nests are numbered 1-5; 2 physogastric queens were collected in nr. 1, and 25 in nr. 2, each with several royal chambers and a variable number of queens in each chamber. Fortaleza, State of Ceará, Brazil.

restricted to the upper floors of the high buildings) are a reality in Recife.

In Fortaleza it was possible to document cases of infestation by *N. corniger*, where the nests are typically polycalic (Fig. 10).

Case 9. Vitória, State of Espírito Santo, Brazil. *N. corniger* seems to be responsible for much of the urban infestation in the city of Vitória, in the east region of Brazil, according to information of Mr. Edson D. Rocha, agronomist and PCO who collected one sample of the termite.

Endogenous (or subterranean) pattern

This pattern is characterized by the presence of the typical tunnels

Fig. 11. Dark tunnels of *Nasutitermes bivalens* in an inner wall of a basement. Note dark marks of tunnels that have been removed. Belo Horizonte, State of Minas Gerais, Brazil.

of *Nasutitermes* (Fig. 11), but the nests are not visible in exposed places. Arboreal nests are also not found on trees, only tunnels are visible outside the trunks and branches.

The nests, although similar to those of the typically arboreal species of *Nasutitermes*, are constructed in hidden places inside the buildings and are protected from direct sunlight. They are found in walls and columns in rooms, passages, basements, and inside a variety of structural voids (like shafts and ceilings; Fig. 12) and cavities bellow the floor.

It is interesting that the termites avoid exposed places to construct the nest. If a wall is exposed to daylight, the nest is always found in the

Fig. 12. Large carton mass of *Nasutitermes bivalens* inside a roof structural void. Belo Horizonte, State of Minas Gerais, Brazil.

non-exposed surface, inside the building. Even if the nest is very large, there is no sign of its presence (except termite galleries) in the outside wall. In the infested trees, the nests are also constructed inside the trunk and roots and are not exposed as typical arboreal nests. As far as we know, there is no report of such lucifugous behavior in *Nasutitermes*.

The species reported here is tentatively identified as *N. bivalens* (Holmgren) by L. R. Fontes, as large and small soldiers are common in the samples studied and they fit reasonably the original description.

Case 10. Belo Horizonte, State of Minas Gerais, Brazil. The urban infestation by *N. bivalens* in this important city is becoming expressive in the last 10 years and is restricted to some areas of the city, excluding the downtown area. It looks a good example of introduction of a pest termite, which is expanding its geographic range in the urban area. We illustrated the infestation with two case studies.

The municipal Stadium “Mineirinho” (Pampulha District) was built in 1979 and became infested in 1982, when nests appeared inside the building. It is still heavily infested, despite the efforts of the caretaker, who informed us on March 2001 that he once removed a great mass of carton that obstructed a water passage in the ground floor, and that he has been continuously removing nests from the inner walls. Nowadays, nests sometimes appear in the top of the inside walls in underground

rooms and passages, in the large chambers below the stands, and are common in hidden cavities in the walls, floors and ceilings (Figs. 11-12).

Two large and high buildings (Sion District) have a common basement in a steep incline. Inside that enormous artificial cavern, humid, warm and inhabited by bats and American cockroaches, there are more than 15 enormous nests of the termite (some have been removed and only their dark spots remain in the walls), at variable heights in the walls and concrete columns (Fig. 13). Some nests are about 4 meters above ground level, while a few are near the ground. Three nests, at great height, measured about 2 m in height, 1.5 m in width and project about 0.5 m from the walls. They have a coarse and dark surface. Tunnels in the walls near the nests can be as broad as 8 cm. The five basal floors of the buildings are infested by the termite. Biologist Horácio C. Cunha, an experienced local PCO, informed that in a close neighbor high building, in that the basement is not sealed by walls and the steep terrain is exposed, several nests of the termite have been removed. All nests had been found in hidden places, away from daylight.

According to Mr. Horácio C. Cunha, infestation by *Nasutitermes* is recent in Belo Horizonte. His first request to control a *Nasutitermes* infestation dates from 1993, in the Sion District. As a biologist, he loves observing urban pests and he remembers clearly that the first noticeable swarming of alates, remarkable by the large amount of specimens in flight along many streets in the Sion District, occurred in October 2000.

Case 11. Piracicaba, State of São Paulo, Brazil. Infestation by *N. bivalens* is restricted to few areas, excluding downtown. In the Vila Resende District, infestation in houses and trees are common. According to information of an ancient local resident, the problem arose about 6 years ago. He attributed the introduction of the pest to the work of sawmills that existed in the area until the beginning of the 90's and would had imported infested timbers.

Infestation by opportunistic species of *Nasutitermes*

Native species of *Nasutitermes* can be opportunist pests and attack structural timber under favorable circumstances. This is more frequent in rural buildings, and severe damage to historic farm houses is reported (Paiva, 1998).

We identified *N. aquilinus* (Holmgren) damaging the roof beams of a badly preserved historic farm house in Americana, State of São Paulo. The same species causes damage to rural properties in Corrientes, Argentina (Torales, 1998: 420).

In São Paulo, State of São Paulo, the greatest urban area in South

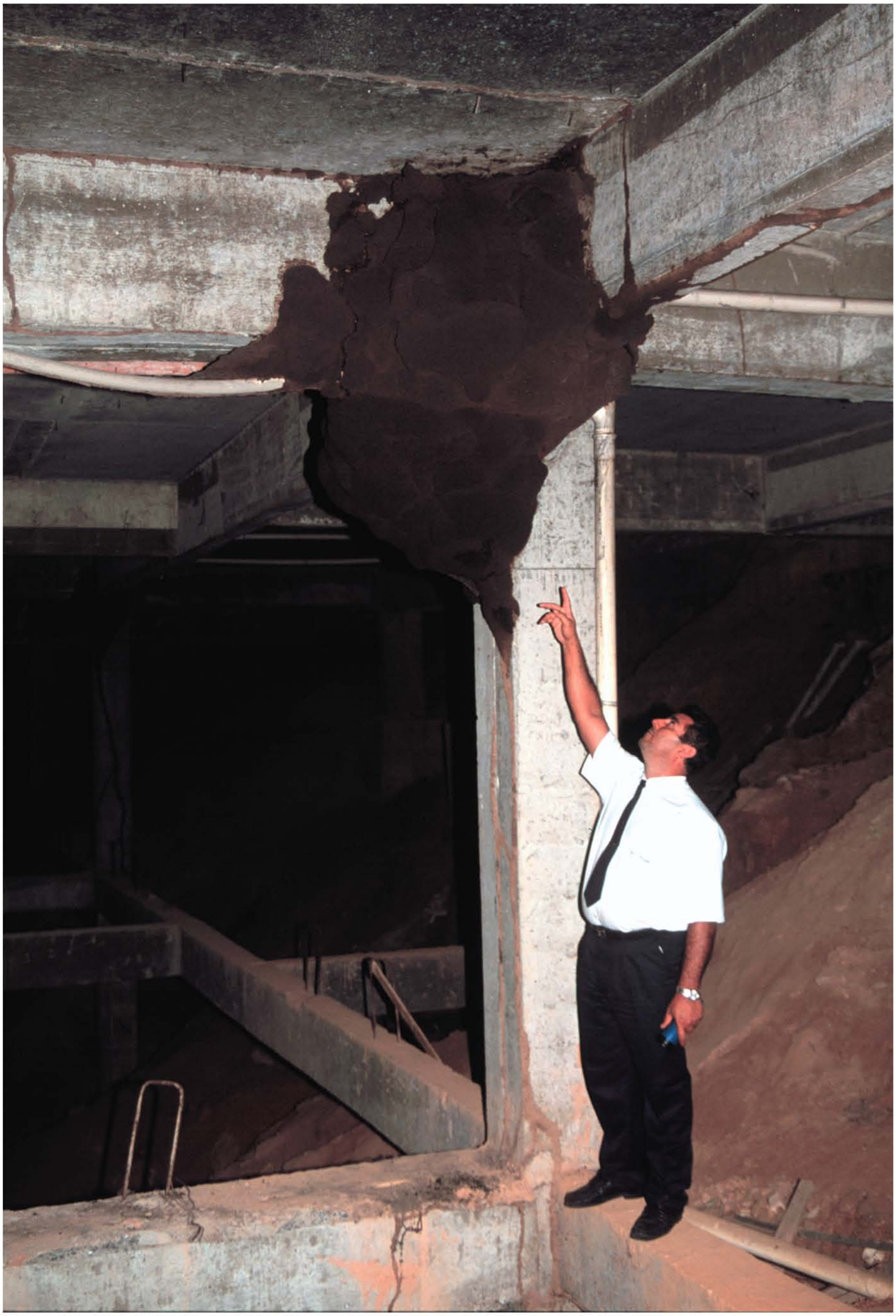

Fig. 13. Giant nest of *Nasutitermes bivalens* at the top of a concrete column, inside a large basement in a steep incline. Belo Horizonte, State of Minas Gerais, Brazil.

America, there have been sporadic attacks of *N. ehrhardti* (Holmgren), to wood shelves, door frames and papers (Vila Mariana District), to fences and poles (Conceição District), and to the structural timber of a floor (Tamboré District, collected by Mr. E. Sayegh). Damages are of minor importance.

MICROCEROTERMES

Infestations by species of *Microcerotermes* in South America are scarcely documented. In the northeast and north regions of Brazil, they appear to be mainly opportunistic pests, invading buildings mostly from colonies located in urban trees and causing more damage to fences and pieces of wood exposed to direct sunlight (Bandeira, 1998: 91-92; Bandeira *et al.*, 1998: 82). Mill (1991) reported that *M. exiguus* (Hagen) and *M. arboreus* Emerson are domestic pests and attack wood structures in the Brazilian Amazon region.

In some regions, *M. strunckii* (Soerensen) can play a role as major urban pests, as in the northeast region of Argentina, building nests on roofs and walls and causing severe damages to structural wood and paper (Torales *et al.* 1995; Torales 1998: 422-423).

We examined with PCO Alexandre P. Vasconcelos an attack to a brick house in Fortaleza, State of Ceará, Brazil, by a species of *Microcerotermes*. The termite has invaded the house by tunnels in a perimeter wall and from the soil in a few other points. It has damaged roof wood beams and a kitchen cabinet, excavated the plaster of some walls and attacked the nearby baseboard, and explored the small hollows behind the tiles of the kitchen walls. Its arboreal nest was found in a tree trunk, in a close neighbor's property. The infestation looks opportunist.

SOIL DWELLING AND MOUND BUILDING TERMITES

Mound building and soil dwelling termites are sometimes opportunist pests of buildings, although in some regions they are reported as important pests. They are frequent in urban gardens, and sometimes can extensively destroy lawns in yards and football fields, as reported for *Syntermes nanus* Constantino and *S. praecellens* Silvestri in Santo André and São Paulo, State of São Paulo (Fontes 1998b: 215). Also *Neocapritermes opacus* (Hagen) can cause some harm to large yards in the cities of Ibiuna and São Paulo, State of São Paulo.

In the genus *Amitermes*, major damages to structural wood is attributed to *A. excelens* Silvestri in Boa Vista, State of Roraima, in the Brazilian Amazonian region (Bandeira, 1998: 92), and to *A. amifer* Silvestri in seaside houses in João Pessoa, State of Paraíba (Bandeira *et al.* 1998: 82). *A. amifer* is also a minor opportunist pest in the urban

areas of Northeast Argentina (Torales 1998: 423-424).

Cortaritermes fulviceps (Silvestri, 1901), a mound building termite common in Southern Brazil, Northern Argentina and Uruguay, is reported as a minor pest of urban buildings in northeast Argentina (Torales, 1998: 421). Attacks to the structural wood of roofs and walls occurs also in Florianópolis (Fig. 14) and Palhoça (Fig. 15), State of

Fig. 14. Earth mass of *Cortaritermes fulviceps* at the base of an outer wall. The floorboards inside the building have been damaged by the termite. Florianópolis, State of Santa Catarina, Brazil.

Santa Catarina, where the termite seems also to be a minor pest (unpublished observations of the senior author in 1986).

Case 12. Two curious invasions of buildings by the common mound building termite, *Cornitermes cumulans* (Kollar), were reported (Fontes & Martins 2000) in the urban area of Rio Claro, São Paulo State. Its earth mounds are very common in pastures, road borders, lawns and other open lands in south and central Brazil, Paraguay and northern Argentina. One case occurred in October, 1994. In a one-story brick house, at the sunset, many winged imagoes arose from a small hole located between a wall and the floor of a bathroom, surrounded by many workers and soldiers. Most walls and floors were tiled and in the outside of the house (almost 8 m far from the bathroom) a small area of soil was covered by grass. No mound was found in the neighborhood in this occasion. A second case was observed from October 1999 to March 2001, in a one-story brick building at the University. A small mound

Fig. 15. Mark of a previously removed mound of *Cortaritermes fulviceps*, inside a garage. The boards have been damaged by the termite. Palhoça, State of Santa Catarina, Brazil.

made of red soil appeared at the base of a wood rabbet of an inner door (Fig. 16), which was slightly damaged by moisture, close to a cold room. The mound was 18 cm high and 12x8 cm wide and some workers and

Fig. 16. Invasion of building by *Cornitermes cumulans*. Small mound made of red earth at the base of a wood rabbet of an inner door. Rio Claro, State of São Paulo, Brazil.

soldiers constantly occupied the outer chambers. The floor of the building was tiled. Outside the building, 5 m away, the soil was covered with grass but no mound was visible anywhere. Both cases are not true infestations, since no visible damage was inflicted to the buildings. The termites just invaded the buildings from the nearby soil. In the first house, they opened a hole for the swarming of the alates from a mature subterranean colony. In the second building, they apparently only explored the area through small cavities in the base of a slightly rotten rabbet of a door.

Opportunist invasion by *Syntermes nanus* was observed by Dr. J. R. Valério in Terenos, State of Mato Grosso do Sul, where the termite invaded the loose tiles of the floor and walls of a farm house. Another case is the invasion of the basement of a house by *Syntermes* sp. in Itaipava, State of Rio de Janeiro, where the termite accumulated great piles of granulated earth, like they did around the foraging holes in the open fields and lawns around the house (biologist and PCO Francisco J. C. Ferreiro, personal information). Two additional cases, that have resulted in damage to houses, have been reported by biologist and PCO Walter Amorim, also in the State of Rio de Janeiro. One occurred in 1998, in a suburban house constructed at the top of a hill in Itaborai District, Niterói city. The termite excavated so strongly the soil below the

house foundations that cracks appeared in the walls. The other case evolved similarly to the latter and was reported in 1999, in a house built at a slope in Jacarepaguá District, Rio de Janeiro city.

DISCUSSION

Some topics must be pointed out, in order to understand the problems caused by termites in South American urban areas. We will refer to our experience in Brazil, which may be a good example to other countries.

South America is a large continent, mostly within tropical limits, and with a diverse fauna of termites. Many species are remarkably abundant and may be a distinctive landscape feature in some regions, like the common mound building termite of the pastures and open lands of the southern half of Brazil, *Cornitermes cumulans* (its popular name is “the little mound-dwelling termite”). Termites are adapted to a great variety of habitats, either natural or modified by man, like agriculture, forestry and pasture lands, including any kind of built structures added to them, and urban areas. ‘Urban area’ is just a general term, because these areas are not homogeneous. Indeed, the variety of urban pictures reflects the great diversity of human cultural patterns, scattered in so many geographically distinct places, as well as, historically speaking, of building and landscape gardening concepts and techniques that have succeed in the last century decades. Cities are thus a dynamic environment within each physiographic and climatic regions, tempered with paste and present, and with the social, economic and cultural aspects of the people living there.

The termite fauna adds a double component to the urban infestation issue. The species of the native fauna are commonly benefic to the urban environment (as to other man-modified environments; see the short account presented by Fontes & Araujo, 1999: 44-48), although some species may become pests or act as opportunist pests under favorable circumstances. Differently, the foreign species that have been introduced into the continent are all destructive pests, voracious and well adapted to the urban environment, and ruinous to man-made structures. Species of the latter group seem to be typically “urban termites”. Of course, it is not a so simple picture, as components of the native fauna can also be aggressive to the city organism and can be introduced into other regions, gradually expanding their geographic limits.

With a so great diversity of cities and termites, it is clear that the problems caused by termites are typical of each region, even within a same country. Generalizations about pest termite concepts and control techniques are not necessarily applicable to regional problems and may

act, indeed, as deleteriously as the pest termites.

Understanding the Problems Caused by Termites in South American Urban Areas

Historically, termite control in Brazil has focused on three main wrong guidelines. First, control is based mainly on concepts imported from European countries and USA, that have been developed for different termite species, climates, physiographic features, and different urban and social realities. Another error is to focus control activities mainly on the building, as if termite infestation was a "building disease" or a "disease of wood in man-made structures". Finally, a crucial error is to consider that termites are enemies of mankind and to spread (or to be omitted in correcting it) such a stupid idea among the population, PCOs and in some scientific and academic milieu.

When we started thinking seriously about urban infestation by termites in Brazil, we have not considered the termites themselves as a problem, but the urban area and its constellation of variable conditions (Fontes 1995; 1998a: 112-113). The latter includes geographic, climatic and pedological features, building practices and patterns of building structures (soil declivity, texture and humidity; leveling and excavations at the building site; site landscape; foundations; discharge of wastes inside structural voids; use of wastes in the structure, as to fill up cavities in the soil; building materials; slabs; walls; wood forms; structural voids; isolating layers or isolating structures; hydraulics, electric and telephone fittings; architectonic solutions, and many other), proximity between buildings, patterns of use of the urban soil (subterranean structures; building in steep slopes and in river plains covered with compacted earth and debris), management of demolition debris, landscape gardening practices, planting and management of urban trees, paving, pollution of soil, water and air, all of these changing in space and time intervals and combined with the also changing social and economic levels of the local people and their cultural practices (including the practices of pest control companies). The listed subjects are not complete within the urban complexity, but give an idea of it. Termites are just one more ingredient within this universe. They are not only passive of urban stress, but actively contribute for the construction of that dynamic universe.

The concepts presented by Fontes & Araujo (1999: 47-48) will spare us a longer explanation about the title subject. In the sections named "termites in the man-modified environment" and "termites in urban areas", they remarked that the **termites are beneficial, although some species of termites are pests**, and, considering the pest

termites, that the **drywood termites interact with the food, whereas the subterranean termites interact largely with the environment**. Now it is clear that the latter concept should include also the arboreal pest termites. The environmental termite interaction includes all subjects listed in the above paragraph, that is, with the physical and biological elements, with the human practices in a broad sense, and it occurs according to the ability of the termite to respond to the urban organism stimuli.

Understanding the two concepts presented above, within the complexity of the urban organization, is fundamental to achieve a clear view of the urban infestation by termites in tropical environments (and perhaps in any environment). It is not the simple knowledge of aspects of termite biology, of control techniques and products, or the transport of laboratory information to the urban field reality. Understanding the body of complex interactions among termites, humans, and man-made and man-modified structures and habitats, comprises what we termed the **dynamic of the urban infestation**. To put it in a few words, we study the dynamic of the termite urban infestation by a simple method: we look at the termite, and watch what it makes. This means that no foregone conclusion is acceptable: the termite is the protagonist and reveal us what it makes. What a better place to do it, but in the urban environment?

São Paulo City, Brazil, as a Case Study on the Evolution of Subterranean Termite Infestation and Control Concepts

The large city of São Paulo, in the Brazilian southeast region, is a great laboratory for urban termite studies. Both authors have always lived there and have witnessed the initial manifestations of the exotic subterranean termite, *Coptotermes havilandi*. We will outline the evolution of the control concepts in that complex urban environment.

Prior to the appearance and rise of the subterranean termite, damages were caused by the common drywood termite, *Cryptotermes brevis*. Infestations by other termites, like *Heterotermes* and *Nasutitermes*, have always been rare and regarded as minor problems.

We recognize four historic phases. They are more recent and have not evolved linearly, so that dates are just approximate. In the future decades, it will perhaps be possible to look at a more “distant past” and to obtain a clearer historic view.

Phase 1 or Pre-Cognition Phase

In its early times (before 1970), urban pest control was performed by few companies, that exploited a little known subject and whose technicians were not cognizant about pest biology. Control was based

mainly on the application of chemicals. The words of one of the pioneering PCOs (Silva, 1987) summarize very well what happened: "... *there were 3 or 4 companies ... the client did not know what he wanted, we did not know what he wished or needed ... [the client] requested an application [of chemicals] ...*". The control of urban pests was a very secondary activity, performed by weakly prepared people and whose economic and social significance were unknown. Clients and PCOs valued the power of the "chemical toxicants" (then considered the main tool in pest control), mainly of the organochlorines, and the concept of pest eradication. To work on urban pest control was not regarded as an honorable career, especially by the academic and scientific staffs (indeed, this has changed only very recently in Brazil, in the last 7 or 8 years).

The experience of the local PCOs was restricted to the control of drywood termites and infestations were regarded as wood problems. Chemical treatments were directed to wood, independent of the infesting termite. PCOs did not collect the pests they were trying to control, so that, when the subterranean termite appeared in scene, control continued to be directed to the wood in buildings and furniture. No research institution then worked on the control of urban termites.

As stated in the species section, large swarmings in São Paulo were noticeable in the ending 60´s or beginning 70´s. Introduction evidently occurred in early decades, most probably in the downtown area and its surroundings. Swarmings were restricted to that region, that then concentrated the most intense city commerce, including the provision market and other. This historic phase extended approximately until 1986.

Phase 2 or the Subterranean Termite as a Soil-Dwelling Termite

The subterranean termite appeared as a major problem in some areas of the city. Attacks affected, in the beginnings of the infestation period, the downtown area, a crucial and economically important region, with many offices, banks and trade activities.

In 1975, Institute of Technological Research (IPT, where the junior author worked from 1974 to 1986), in São Paulo, the Brazilian pioneering research institute on wood technology, started investigations of termite control in buildings. The first training courses on wood preservation and termite control were ministered in the end of the 70's and beginning of the 80's. These courses commonly were attended by few PCOs. IPT was also the pioneer in the edition of the first book, in Portuguese language, with a large chapter on wood destroying agents, including also non-biological agents (Oliveira *et al.*, 1986), and a chapter on their control, focused mainly, but not exclusively on termites

(Lepage *et al.*, 1986). This book marked the beginning of historic phase 2.

Control has finally been based on scientific information, explained in the book published by IPT. The technological approach then adopted to control the termite infestation was based mainly on the traditional concepts and practices. Control methods were adapted from the literature on subterranean termite infestations in European countries and USA. As a rule, it was recommended chemical treatment of the soil for controlling the infestation, and of the wood for preventing return of infestation. It was a generally accepted idea that all infestations come from the ground or had obligatory contact with the ground. The methods used to control *Reticulitermes* infestations in USA and Europe were accepted and chemical treatment of the soil was obsessively recommended for eradicating all cases of *C. havilandi* infestations, even those installed in the upper floors of high buildings. In addition to soil treatment, chemical treatment of the wood was universally adopted as a tool for preventing reappearance of infestation, if the termite was able to surpass the soil chemical barrier.

In this period, the subterranean termite has extended its geographic range in the urban area of São Paulo, far beyond the downtown and surrounding region. The new infestations radiated out from the central introduction region, what suggests strongly a slow dispersion by swarmings. This was confirmed by Milano (unpublished) in 1999. He had previously studied two urban buildings that he knew exactly when they became infested by *C. havilandi*, and this enabled him to estimate the dispersion rate of the infestation between the two buildings as 250-300 meters/year. Such a result agrees with a swarming dispersion pattern. He also calculated that, if the termite had been originally introduced in the downtown area, then it happened in ending 1950's or beginning 1960's. These dates are also compatible with the first noticeable swarmings, known from beginning 1970's (Araujo, *in* Mariconi, *l.c.*: 111; personal communication of R. L. Araujo to the senior author in 1978).

A malappropriate term arose in the beginnings of phase 2 and resulted (and still results) in much confusion and misinterpretation of urban infestation issues. That is the designation of the subterranean termite as "soil termite" (meaning soil-dwelling termite). Despite the efforts of the authors, this term is still much in use, either by common people as by applied technological and scientific researchers, among who incredibly it has found defenders! This historic phase expired around 1990.

Phase 3 or the Subterranean Termite as a Building Disease

Time is up and the city greatly increased its population and geographic area. The urban picture changed to a vertical profile of large and dense high buildings. Some building construction techniques, adopted in the two previous decades, were noted to favor infestations strongly by subterranean termites. By reason of economy, much of the construction wastes, that should have been discharged, were inside the building structure, accumulated under the ground floor, under the kitchen and bathroom slabs in upper floors, or in other structural voids. Also, there were too many structural voids, added to the building for esthetic or other reasons, and high humidity was favored by closed voids and metal hydraulic pipes. All of these enabled termite colonies to be installed inside the building, from the ground to the top floor, to favor high infestation levels and they caused serious trouble for control activities.

Soil infestation still was a concept universally adopted, but the control strategies were strongly focused on the nests inside the building structure. Aerial infestations were common inside structural voids and these nests should be found and removed, in order to control the infestation.

Despite the scientific approach, subterranean termites were regarded basically as a disease of buildings. Their occurrence outside buildings, like in street and garden trees, was recognized, but the real problem was considered to be the close interaction of termite versus building.

PCOs were much interested in the problem of urban termite infestation, considered by them a promising working field, although difficult and requiring specialized knowledge and skill.

In the meantime, *Reticulitermes lucifugus* has arisen as a problem in the city of Montevideo, Uruguay (Aber & Fontes, 1993) and a scientific meeting was organized there in 1992. A second meeting, despite its regional scope, was organized in 1993 in the city of Rio Claro, near São Paulo, and was attended by dozens of PCOs from São Paulo city, that were looking for information on the control of *Coptotermes* infestations. This historic phase continued until around 1998.

Phase 4 or the Subterranean Termite as an Environmental Component

From 1993 onwards, a new set of environmental concepts, related to subterranean termite infestations, was communicated in lectures and published in 1995 (Fontes, 1995). Additions were presented in further texts (Fontes, 1996; 1998a; Fontes & Araujo, 1999).

The first step was the introduction of the urban trees in the termite

problem. In São Paulo, as is true for many other cities, urban trees are an important reservoir of *C. havilandi*. Living trees, stumps and tree subterranean remains can contribute to the prime infestation of buildings, to the return of infestation to treated buildings, and to unsuccessful control operations. Trees are also subjected to infestation that comes from infested buildings. But trees are only part of a major organism, and the complete concept included a trinominal composed of termite biology, urban complexity and pest control operations.

Termite biology expresses the potential of the species as a pest. It determines the full range of damage and activities of termites in urban areas, some of which have initially surprised experts on termite control and scientific researchers. As an example, we mention the ability of *C. havilandi* to consume (or, more correctly and updating previous biological information, the avid or enthusiastic consuming of) gypsum artifacts and other calcium rich products, like the plaster covering of brick walls. Another example is the capacity of the termite in excavating bitumen used to seal floor slits.

Urban complexity includes the set of characteristics presented in the previous item, subjected to spatial diversity (heterogeneity of habitats and of building patterns in a same city) and to historic diversity of methods, materials and urban practices in the course of time.

Pest control operations can encourage a termite infestation, if it is underestimated and receives partial treatments (if only chemical treatment is considered, treatment is also partial). Conversely, an overestimated infestation adds excessive cost, client disturbance and environmental or building contamination with chemical products.

The trinominal or environmental scope express a more comprehensive concept on the urban termite subject. It means that complex interactions determine the success of the termite in the urban habitat, as well as of the control operations. It means also that tradition, either from scientific studies of the pest biology, as from skill obtained from field control activities, is unsatisfactory and cannot determine the major control guidelines. Control is not dependent exclusively on scientific knowledge and practical skills, or on the sum of these factors. It is essential to add a broad urban view, in its full spatial and time dynamic and complexity. A broad urban universe approach, considering buildings and their complete surroundings, all kind of man-made structures, termites, previous control operations, history and culture, is required to harmonize a serious control work. Termitologists are especially requested to assimilate this broad view.

From that time on, a series of urban investigations was and is being conducted by the authors in São Paulo and other cities. They consoli-

dated previous ideas about the environmental role of subterranean (and also arboreal) termites in urban areas, and the complexity of the human, termite and city interactions. The research tool employed in understanding such complex problem is the study of the dynamic of the urban infestation by termites, which concept was explained in a previous item.

Conclusive Remarks on the Historic Study

The introduction and dispersal of the subterranean termite in São Paulo appeared as a disruption in the urban organization. Control has been a major challenge for local PCOs. But PCOs and scientists have benefited from that apparently unfortunate fact, because many urban concepts had to be revised and are changing. It was a power for good, if we consider that there is a slow, but gradual evolution of concepts related to building engineering and architecture, landscape gardening, preservation of historic and cultural goods, and urban pest control.

In practical terms, currently many PCOs in São Paulo still develop their control work as described for historic phases 1 and 2. The control performance of most of those classified within phase 3 is not yet in full accordance with the concepts required by phase 3. But great progress was obtained in the last 10 years and Brazilian PCOs take advantage of the São Paulo experience. Phase 4 is just beginning.

A deleterious hindrance on control course, however, still survives in Brazil. It is the wrong concept of *C. havilandi* as a soil-dwelling termite (vulgarly named "soil termite"), referred in historic phase 2. We list five good reasons to banish that nonsense and refer correctly to *C. havilandi* as a subterranean termite. Subterranean termites (1) compose a well-defined taxonomic group (family Rhinotermitidae), what (2) common designation is readily recognized worldwide. (3) They explore the soil (excavate tunnels and use soil particles as modeling material, but these are not obligatory tasks) in their search of wood, while soil-dwelling termites are dependent on the soil for food, water and shelter. The wrong concept (4) induces common people to consider soil-dwelling termites, common in gardens and lawns, as pests of buildings, and causes a behavior that ranges from the simple fear of termites to an unbalanced and obsessive fright of termites. It also (5) causes PCOs to assimilate the false idea that any termite found in the soil is a pest, so that they propose costly and unnecessary chemical treatments to their clients.

Why has *Coptotermes havilandi* Evolved as a Major Urban Pest in Southeastern Brazil?

It is not a creative input to ecology to state that termites are the main

decomposers of wood in southeastern Brazil. But is worth remembering that the urbanization process affected very strongly the harmonious composition of the original fauna in the places now occupied by metropolises in that tropical region. Cities like Rio de Janeiro and mainly São Paulo have too many people, buildings and areas covered by concrete and paving. This has not happened suddenly, but composes a process in the course of the last 30 or 35 years, intensified in the last 20 years. The urban profile changed drastically and, for a long time past, *Syntermes praecellens* and *S. nanus* were captured by the authors from their holes in the soil surfaces with the aid of a delicate grass stem, in the open fields of the then suburban districts of Jabaquara (type locality of *S. praecellens*), Congonhas and Ipiranga, in São Paulo city.

Details of the historic evolution of *Coptotermes havilandi* in São Paulo are presented in the species section and in the previous item. However, why has it become a so important urban pest? Obviously, the changes in the natural ecosystem, the strong urbanization, the biology of the termite, and our previous wrong concepts about the species, all have contributed to the success of the termite. But the specific contributions of each of those subjects is merely speculative. For example, is the lack of predators in the urban environment an important cause of *C. havilandi* success? Or the lack of lawns and gardens in the general urban landscape? Again, the city of São Paulo is our domestic field laboratory and we have made a series of field observations that furnish some hints about this issue. Two illustrative cases are presented below.

Case 13. The senior author worked for 18 months, in years 1995 and 1996, at the University of São Paulo mayor office (Butantan District), as advisor on termite infestation and control. The campus has large buildings, separated by extensive lawns with many trees. Trees are commonly isolated, but in many places their crowns touch each other and constitute a canopy. Birds, spiders and a great variety of insects are common, and the campus is a really enjoyable place, despite the existing vegetation is totally divorced from the original vegetation that covered that area. Infestations of *C. havilandi* were diagnosed in buildings and trees, and it was surprising that trees in some extensive and nice lawns were also infested. In some places, trees were important reservoirs of the termite and exchanged infestation with buildings (see Fontes, 1998a).

It is clear that the simple presence of extensive urban lawns, trees and diverse fauna do not interpose a serious obstacle to the introduced subterranean termite.

Case 14. An urban park at the back of the Paulista Museum (Ipiranga District), in spite of being affected by the urban influence and by people,

still preserves a fragment of the original Atlantic forest environment, inside the city area. It is crossed by cleared passages for walking and sports, but outside the passages the ground is covered by a litter layer of decaying fallen leaves and humus. Trees are high and relatively dense, the canopy results in a shady environment, and direct sunlight only reaches the floor in small, local flecks and only during the middle hours of the day. The shrub layer is, however, very poorly represented and is being constantly cut down. The forest is surrounded by buildings and streets, and its margins are exposed to sunlight or influenced by surrounding buildings and walls. It exemplifies a typical forest fragment under strong urban influence. Large swarmings of *C. havilandi* occur in that district at least since 1990, according to the observations of the junior author, who has lived there since his birth. Such swarmings can easily cover all the forest area. In middle 2001, we explored the area and noted that the soil-dwelling termite, *Procornitermes lespesii* is very abundant, followed by *Neocapritermes opacus*. The density of *P. lespesii* appears impressively high and this is probable the result of the urban influence on the forest. It is very interesting that *C. havilandi*, despite infesting many trees in the Museum gardens and in all the nearby streets, invaded only the trees at the forest margins. Some of the infested trees had their trunks hollowed out by the termite, and some have been removed, because of the risk that they could fall and hurt people or destroy perimeter walls.

Although it is not conclusive, it seems more likely that the dominant soil-dwelling termites are strong competitors and prevent invasion of their habitat (including the trees inside the forest) by the introduced subterranean termite.

Very few has been studied about urban ecology in Brazil. These two cases raise the issue that the native species in the soil and woods are strong competitors, that can make difficult or avoid the proliferation of pest species. The same mechanism should also prove to be important in culture lands and pastures. In strongly modified urban areas, the construction of high buildings, that are necessarily preceded by the removal of the top soil, sometimes to considerable depths, and its substitution by extensive areas of new soil, artificially covered by lawns and trees, results in the extinction of the original soil environment and its termite fauna. The vacant niche can be occupied by the pest subterranean termite, *C. havilandi*. Perhaps does this process explain the recent proliferation of the same pest termite in Recife (see Case 1)?

Does the Occurrence of Termites in the Building Area and its Surroundings Represent Risk of Damages?

The cities in tropical regions can preserve part of the original fauna of termites. Although the stress represented by the urbanization process probably forced the disappearance of several native species, others can survive in vegetation preserved areas and other are adapted to the new conditions represented by urban parks, gardens and buildings with preserved green areas. As an example, in the city of São Paulo, the greatest urbanized area in South America, very polluted, densely populated and with few green areas, 18 species of termites were identified (Fontes, 1995: 59). These include the introduced pests, *Cryptotermes brevis* and *Coptotermes havilandi*, but the other 16 are native species. In addition, there is a number of unidentified soldierless termites, of the subfamily Apicotermitinae.

In São Paulo, excluding the most dramatically urbanized areas that eliminated every trace of exposed soil surface, native species commonly survive, occasionally in close proximity to buildings. For example, in areas surrounded by trees, gardens and extensive lawns, the mound building termite, *Cornitermes cumulans*, the grass foragers *Syntermes nanus* and *S. praecellens*, and the ground dwelling *Embiratermes festivellus* are common and specimens eventually can be found inside buildings, mainly bellow boarded floors at ground level degraded by humidity and fungi.

Case 15. In the 80's, at the Forest Research Institute, placed in a very well preserved urban park and vegetation reserve, the boarded floor of a one-story building was frequently invaded by a foraging column of a species of *Syntermes*, despite the efforts of the civil-servants working there, that plugged several times the few emerging holes between the floor boards (Dr. Edson P. Teixeira, personal communication, observed also by L. R. Fontes).

In other residential areas in São Paulo, much more urbanized but still with gardens and lawns, we mention *Neocapritermes opacus*, *Procornitermes lespesii*, *Cornitermes cumulans* and soldierless termites, which are common in the soil of gardens (commonly under stones and concrete tiles on the soil surface) and sometimes invading bellow rotten and humid boarded and inlaid floors.

Case 16. In 1997, the senior author visited a nice one-story house in the Brooklin District, city of São Paulo, infested by *Coptotermes havilandi*. In the front part, around the entrance door, the termite obstructed some electroducts and damaged the wood frames of some doors. In the front garden, a tree fell down and the remaining stump was infested. No sign of infestation nor damages were found at the back rooms and the backyard. The proprietor, however, was anxious because she had removed the inlaid wooden floor of a back study room and

discovered some termite tunnels below the floor. According to the previous evaluation of three pest control companies, it would be necessary to treat chemically all the building and to apply a chemical barrier in the perimetral inner and outer walls. She disapproved such proposal, since no evident damages were found at the back rooms and she was afraid of chemical contamination by odor in the backyard and at her studying room. Indeed, what happened is that *Neocapritermes opacus*, common among the roots of grass tussocks and below paving stones in the backyard, decided to invade the rotten woods of the humid floor and constructed tunnels made of dark earth. She was then recommended to treat chemically the area infested by *Coptotermes*, and to correct the water infiltration in the back of her house, without no further treatment in that area. The termite problem was solved, as well as the previously undiagnosed humidity problem.

Case 17. A large house surrounded by an extensive garden with many high trees and shrubs. In 1996, a tree, 10 m away from the house, fell down and it was infested by termites. In the words of the proprietor, "*termites were swarming from the ground, almost daily after rains. Pest control companies have recommended a complete chemical barrier around the house to avoid termite invasion, and removal of the soil of the garden, followed by chemical treatment of the residual soil and also of the new substitution soil*". He was very worried about the insecticide inundation around his house and the health risk this would cause to his family, about the risk of termite infestation of the main house, and about the monetary costs of such enterprise. In 28 September, 1997, the senior author visited the house and was lucky because he arrived at 10 AM at a drizzle and the proprietor, surrounded by some of his relatives, was desperately crying because termites were swarming from dozens of small holes in the ground of that lovely garden. That "swarming in the rain" scene would really be delightful for a termitologist, if it was not for that embarrassing picture of familiar desperation. A careful inspection all over the area revealed that the stump was infested by *Coptotermes havilandi*, but no other sign of subterranean termite infestation was found. The swarming termite was a species of *Aparatermes* (Apicotermitinae). Control recommendations included the removal of the tree stump and its roots, followed by chemical treatment of the root remains, and the care about the garden against *Coptotermes*, with the aid of discrete soft wood stakes applied in the soil. Concerning the swarmings and the presence of termites in the soil, the proprietor was told about the beneficial role of soil-dwelling termites in the soil ecology. The problem was solved.

It is clear that our knowledge about the biology of termites in urban

areas is incipient. The invasions of buildings by *Cornitermes cumulans*, in the city of Rio Claro (see Case 12), show that even in the absence of typical mounds there may exist wholly subterranean colonies of *C. cumulans*, which mature and produce alates and explore the soil largely, including under large buildings. *C. cumulans* colonies are polycalic (Fontes 1998b), a feature that probably enables the termite to explore large territorial areas. Colony maturation without building the typical mound was previously unknown for this termite. Such behavior demonstrates that even under high injurious pressures, meaning destruction of all visible mounds, the termite can successfully survive and adapts to the new condition represented by urban sites. Indeed, this may be true for other situations, like extensive sugarcane plantations in southern Brazil, where *Cornitermes cumulans* is common in the soil, consumes plant debris on the surface, and swarms in the proper seasons, but no mound is visible anywhere (Fontes & Pizano, unpublished).

Mound building and ground-dwelling termites are common in the soil surrounding buildings and can act as opportunist invaders of buildings. They commonly inflict no true damage and only few, probably foraging specimens, are found. These occurrences deserve the particular attention of PCOs. Besides those cases reported above, we know of several chemical control treatments that have been immoderately indicated because inoffensive termites had been confused with the harmful species of subterranean termites (mainly *Coptotermes havilandi*). Such errors mean high economic and environmental costs, and reveal a suspicious competence of many PCOs.

The Role of Brazilian Pest Control Operators (PCOs) in the Scientific Knowledge of the Pest Termites

PCOs have contributed with many specimens and much of the valuable information presented in this paper. They have also selected interesting case studies, to be discussed or inspected by the authors in the opportunity of their visits, courses and lectures.

The meetings and literature referred in the introduction of this paper were intended for scientists and also PCOs, as the latter were previously deprived of scientific background and instructions. It is the authors' opinion that this professional class represents the eyes and arms of urban scientists. They must be encouraged to collect specimens and information, to request scientific investigation of infestation problems, and to publish the results of their field investigations and routine work, if convenient in association with scientists. Brazilian PCOs have proved that this association is profitable.

Future Trends of Termite Control

Control of termites is a major challenge in tropical urban areas, as it is also in agriculture lands. There is a great deal of chemicals, ranging from the old organochlorines of the 50's to the modern very low dosage products and the non-contaminating baits. Diagnosis and control operations also combine a simple screwdriver and modern technology implements. The authors understand that all kind of products and equipment are merely tools for termite control. All have had their time in history and all can be currently used, if they are correctly indicated. This issue is not a frequent concern and, indeed, it is disconcerting to know that scientists and technology researchers sometimes viciously assume that new developments in control technology are the ultimate answers to control. Although seemingly most unintentional, this biased attitude toward an oversimplification of control is injurious to most PCOs, that are not so instructed and look for a standard control prescription.

An environmental approach to control concepts, from our standpoint, is more appropriate to the complexity of the urban universe. The trinomial delineated in the above section is an effort in that direction. Urban areas must incorporate harmony between their physical and biological constituents. PCOs need much orientation on control concepts and practices. Termites are not invited guests, but they appreciate living in urban areas and can teach us much about the urban nature. The dynamic study of the urban infestation by termites gives a more comprehensive idea of the problem and the guidelines of control.

Short to long-term changes of the urban landscape and urban components must be considered within the scope of a Termite Control Program (Fontes & Araujo, 1999: 78-79), instead of an eradication goal. A control program is adequate for drywood termites, as incipient colonies are hardly diagnosed and can cause return of the infestation. It is undoubtedly more effective for the control and follow up of subterranean and arboreal termites. A control program is instructive to the client and also will reduce the risks of damage caused by the unexpected return of the infestation, reduce costs if new treatments are indicated, and enable the PCO to operate properly in case the building or its surroundings are to be remodeled.

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LIST OF GEOGRAPHIC COORDINATES OF CITIES

Alcântara 02º 24´ 32´´ S; 44º 24´ 53´´ W
Americana 22º 44´ 21´´ S; 47º 19´ 53´´ W
Aquidauana 20º 28´ 16´´ S; 55º 47´ 14´´ W
Asunción 25º 18´ 00´´ S; 57º 37´ 00´´ W
Bananal 22º 41´ 01´´ S; 44º 19´ 24´´ W
Belém 01º 27´ 21´´ S; 48º 30´ 16´´ W
Belo Horizonte 19º 55´ 15´´ S; 43º 53´ 16´´ W
Blumenau 26º 55´ 10´´ S; 49º 03´ 58´´ W
Boa Vista, RR 02º 49´ 11´´ N; 60º 40´ 24´´ W
Brasilândia de Minas 16º 59´ 52´´ S; 46º 00´ 50´´ W
Brasília 15º 46´ 47´´ S; 47º 55´ 47´´ W
Buenos Aires 34º 36´ 00´´ S 58º 27´00´´ W
Cabo Frio 22º 52´ 46´´ S; 42º 01´ 07´´ W
Campinas 22º 54´ 21´´ S; 47º 03´ 39´´ W
Campo Grande 20º 26´ 34´´ S; 54º 38´ 47´´ W
Castro 24º 47´ 28´´ S; 50º 00´ 43´´ W
Caxias do Sul 29º 10´ 05´´ S; 51º 10´ 46´´ W
Congonhas 20º 29´ 59´´ S; 43º 51´ 28´´ W
Corrientes 27º 27´ 00´´ S; 58º 46´ 00´´ W
Corumbá 19º 00´ 33´´ S; 57º 39´ 12´´ W
Florianópolis 27º 35´ 48´´ S; 48º 32´ 57´´ W
Fortaleza 03º 43´ 02´´ S; 38º 32´ 35´´ W
Guarujá 23º 59´ 35´´ S; 46º 15´ 23´´ W
Icoaraci 01º 17´ 20´´ S; 48º 28´ 00´´ W
Ilhéus 14º 47´ 20´´ S; 39º 02´ 58´´ W
Itabuna 14º 47´ 08´´ S; 39º 16´ 49´´ W
Itapira 22º 26´ 10´´ S; 46º 49´ 18´´ W
Jacareí 23º 18´ 19´´ S; 45º 57´ 57´´ W
João Pessoa 07º 06´ 54´´ S; 34º 51´ 47´´ W
Limeira 22º 33´ 56´´ S; 47º 24´ 06´´ W
Manaus 03º 06´ 07´´ S; 60º 01´ 30´´ W
Montevideo 34º 53´ 00´´ S; 56º 11´ 00´´ W
Niterói 22º 53´ 00´´ S; 43º 06´ 13´´ W
Ouro Preto 20º 17´ 15´´ S; 43º 30´ 29´´ W
Petrópolis 22º 30´ 18´´ S; 43º 10´ 43´´ W
Palhoça, SC 27º 38´ 43´´ S; 48º 40´ 04´´ W
Pindamonhangaba 22º 55´ 26´´ S; 45º 27´ 42´´ W
Piracicaba 22º 43´ 31´´ S; 47º 38´ 57´´ W

Porto Alegre 30º 01´ 59´´ S; 51º 13´ 48´´ W
Porto Feliz 23º 12´ 56´´ S; 47º 31´ 26´´ W
Porto Ferreira 21º 51´ 14´´ S; 47º 28´ 45´´ W
Presidente Prudente 22º 07´ 32´´ S; 51º 23´ 20´´ W
Recife 08º 03´ 14´´ S; 34º 52´ 52´´ W
Ribeirão Preto 21º 10´ 39´´ S; 47º 48´ 37´´ W
Rio Claro 22º 24´ 41´´ S; 47º 33´ 41´´ W
Rio de Janeiro 22º 54´ 10´´ S; 43º 12´ 27´´ W
Salvador 12º 58´ 16´´ S; 38º 30´ 39´´ W
Santana do Parnaíba 23º 26´ 39´´ S; 46º 55´ 04´´ W
Santiago 33º 28´ 00´´ S; 70º 39´ 00´´ W
Santo André, SP 23º 29´ 50´´ S; 46º 32´ 18´´ W
Santos 23º 57´ 39´´ S; 46º 20´ 01´´ W
São Paulo 23º 32´ 51´´ S; 46º 38´ 10´´ W
São Vicente 23º 57´ 47´´ S; 46º 23´ 31´´ W
Seropédica 22º 44´ 38´´ S; 43º 42´ 27´´ W
Taubaté 23º 01´ 35´´ S; 45º 33´ 19´´ W
Uberlândia 18º 55´ 09´´ S; 48º 16´ 38´´ W
Valparaiso 33º 01´ 00´´ S; 71º 33´ 00´´ W
Vitória 20º 19´ 10´´ S; 40º 20´ 16´´ W